(1)VHF Optimization Investigating Key Related Issues (2)Short Baseline Interferometry for Precision Landing

Summary Of Results

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VHF Optimization Study Objectives

- The objectives of this study are twofold, namely

  - Determine if there is sufficient bandwidth within the existing ATC VHF band to meet transition and capacity needs of the next generation data/voice system for a very long time.

  -To determine if the future system should be half duplex or full duplex

Focus/Data Base

- **This briefing addresses the first objective dealing with bandwidth sufficiency.**
- **Over the past several months I have met with Oscar Alvarez and his staff of the Office of Spectrum Policy and Management who have provided me with the data base upon which the analysis and results of this study are based.**
- **I am indebted to them in helping me gather and understand the data that I have studied.**

The Data Base (2)

- **The data base covers 14 states and provides relevant information for all 2,735 channel assignments. Frequency reuse is required and all of the FAA's allocated 536 frequencies have been utilized to cover these assignments.**
- **536 represents 13.4 MHz of the 20 MHz (790) frequency allocations in this band. ARINC has approximately 4 MHz of this band.**
- **The states covered are CT, IL, IN, MA, MD, MI, NJ, NY, OH, PA, VA, WI and WV**

The Data Base (3)

- For each channel assignment the following information is provided,

  Frequency

  State

  City

  Long.

  Lat.

  Flight Level Radius

Assumptions

- Airspace can be partitioned in the following way

  -Ground control—runways, runway access

  -Local control (from Tower)—up to 3,000 to 5,000 feet

  -Tracon—out to 30miles-up to 10,000 ft.

  -Low altitude control—up to 25,000 ft.

  -High altitude control—up to 45,000 ft.

  -Very high altitude control—up to 60,000 ft.

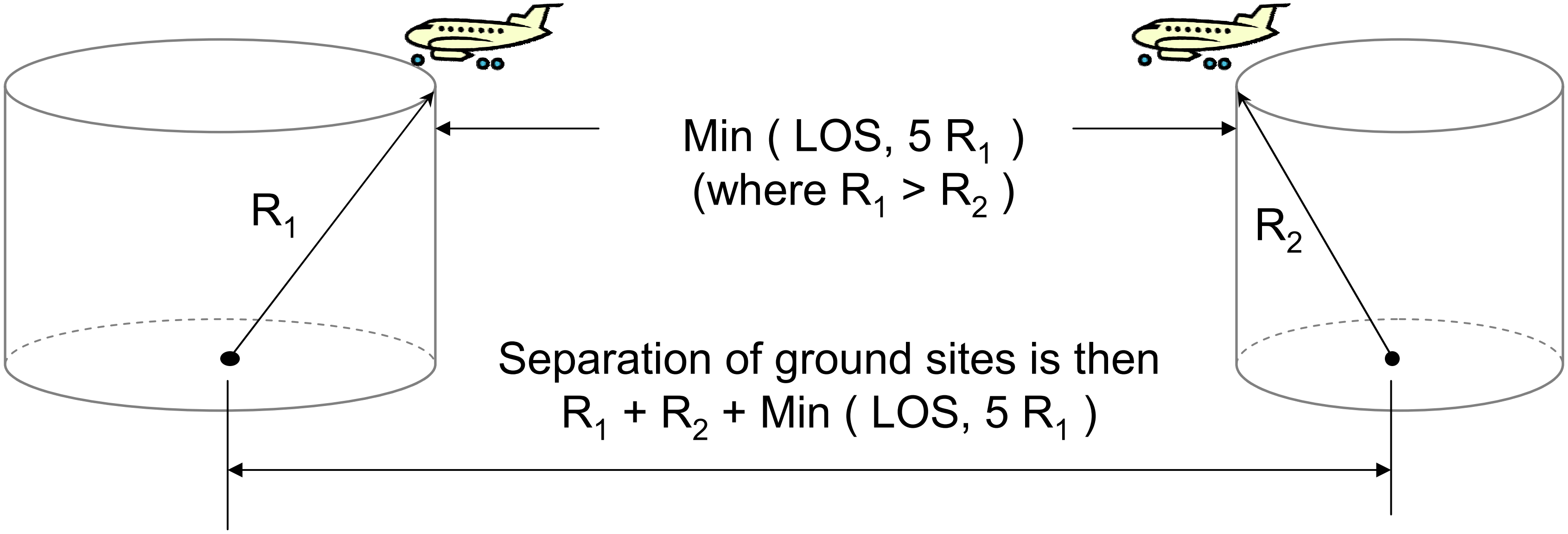
Assumptions (2)

- **Beyond local control, any point in space is under the control of but one controller, so that at any instant of time only one frequency covers that point in space.**
- **Existing ground VHF infrastructure has constrained the FAA so that they have not been able to use the allocated bandwidth more efficiently.**
- **This study does not assume any such constraint.**

Methodology for Determining Frequency Reuse

- If a frequency is to be reused in another control sector it has to meet the separation requirment illustrated in the next slide to guarantee that the S/I is greater than 14 db.
- This separation rule was used throughout the study. If the rule cannot be met it is unacceptable to reuse a frequency.

Separation Rule That Allows Frequency Reuse



Methodology for Determining Frequency Reuse(2)

- For ground control, all data base channel assignments are assumed to be required since multiple controllers need an RF channel connectivity with pilots. The number of channels that can reuse the same frequency is determined by applying the separation rule to the sites specified in the data base.
- The same assumption applies for local control for the same reason

Methodology for Determining Frequency Reuse(3)

- **For all other altitudes the approach taken is to layer each altitude with a set of control sectors that span the area of a state. For each state this is done twice. There are enough sectors given in the database that they span each state more than 6 times at each altitude range.**
- **The first set uses smaller control sectors to support peak hour traffic. The second set uses larger sectors to also span the same airspace. Sector size for each group is based on the average sector size allocated today as given in the data base.**

Methodology for Determining Frequency Reuse(4)

- **Where possible, the separation rule for frequency reuse is based on the off-hour larger sectors, so that the same frequency set can be used for both peak and off hours.**
- **Each layer of altitudes are given a set of frequencies for reuse that cannot be used with any other altitude group.**
- **The 8 altitude groups selected are 1, 20-50, 60-100, 110-118, 119-240, 250-370, 450, 500-600.**
- **Using 8 layers rather than 6 is a conservative approach.**

Result Summary

Altitude	# of frequency channels-peak hour channels	Delta Channels required for low traffic hours
1	20	
20-50	28	28
60-100	77	
110-180	45	
190-250	35	8
260-370	19	15
450-460	20	11
500-600	5	
	249	62

Sub Total	311	
10% reserve	31	
Total	342	8.55 MHz
Today	536	13.4 MHz
Difference	194	4.85 MHz

Issues

- To achieve this bandwidth reallocation, several operational issues have to be accounted for including

  - Site separation constraints on the use of adjacent frequencies.

  - 500 kHz separation of co-sited frequencies.

  - Deployment of new tunable radios.

Observations

- **It appears that at least 36% (4.85 MHz) of the FAA's bandwidth could be allocated for transitioning to the next generation voice and data VHF network.**
- **Proposed transition strategy**
  - **Develop new system including new radios**
  - **During transition use 8 MHz for analog voice**
  - **During transition use remainder of band width (4.85 MHz) for new data services for equipped users**
  - **12 years after start of transition provide only digital and voice services**
- **Note that VDL Mode3 could handle today's voice requirements in less than 2.5 MHz of BW.**

Introduction

2)Short Baseline Interferometry for Precision Landing

- **This paper presents some preliminary analytic results for a concept that employs a precision landing guidance system. The system uses ground-derived measurements based on combined interferometry and ranging, called augmented interferometry.**

RF Interferometry

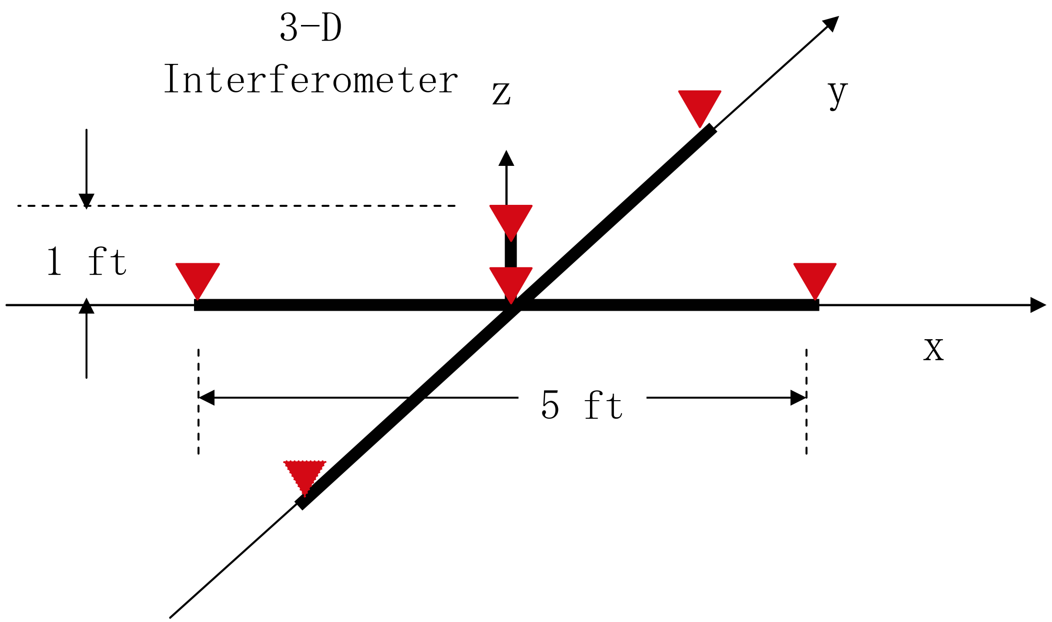
- *RF Interferometry* is the science of measuring the arrival angle of a radio signal by receiving it at two or more points and processing the receptions for information-bearing data, such as:
  - RF phase difference (phase comparison interferometry)
- *Augmented interferometry* is the result of coupling angle measurement interferometry with a range measurement capability
  - Enables full three-dimensional position estimation
  - Assumed ranging method—two-way pseudonoise (PN) code ranging (there are others)

An Example

- The following example provides results which demonstrates that a relatively small augmented interferometer can provide high performance in any one of a wide variety of bandwidths.
- The example uses an omni-directional antenna to interrogate aircraft and only 6 phasing elements.

Approach and Landing Guidance Example

- **Example: Position estimate within approach and landing zone**
  - **0-20 mi from threshold**
- **Assumes uncorrected 20-dB multipath fade**
  - **Results for two frequencies:**
    - **C-band (~5 GHz) and L-band (~1 GHz)**

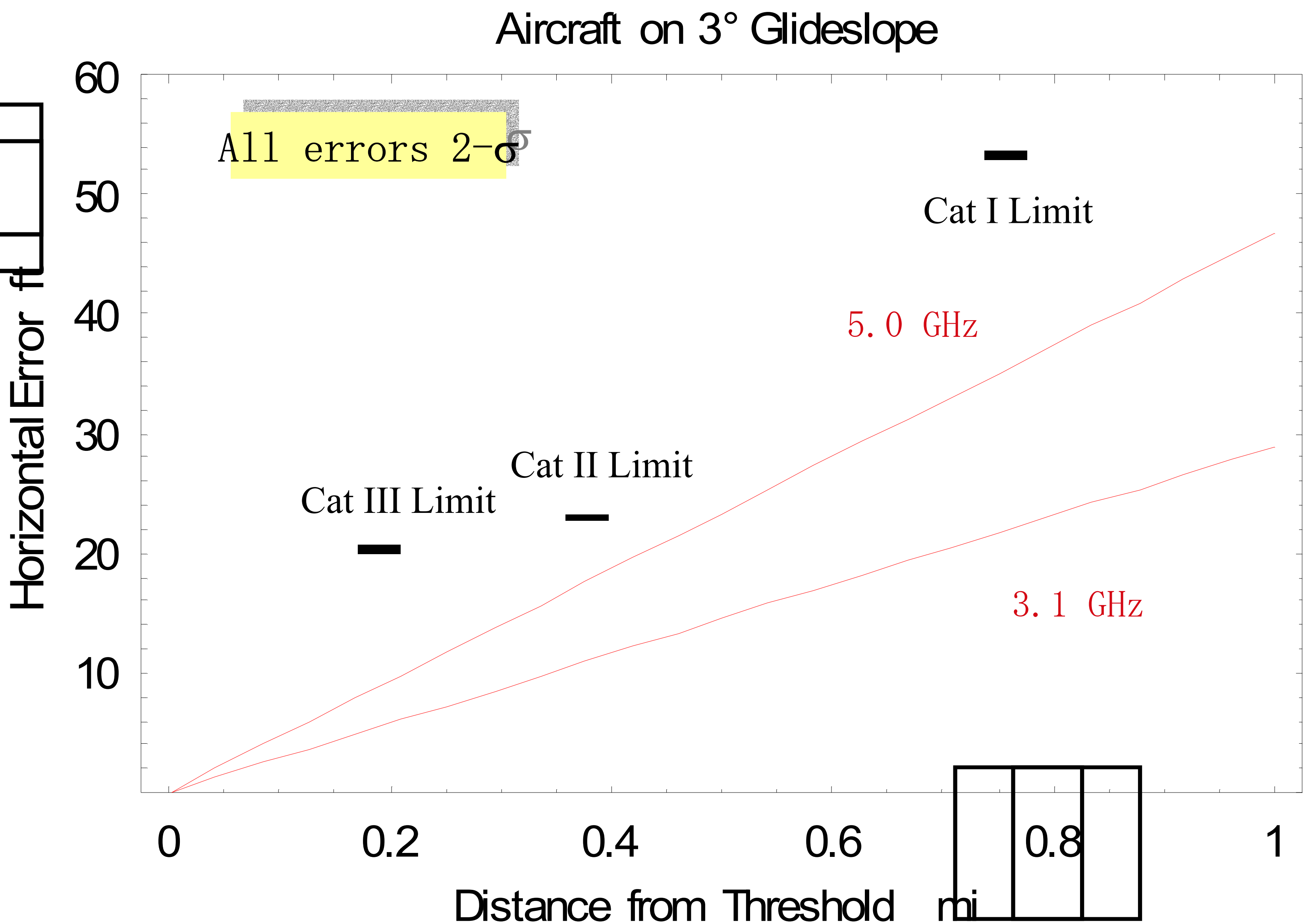


Ambiguity resolution elements not shown

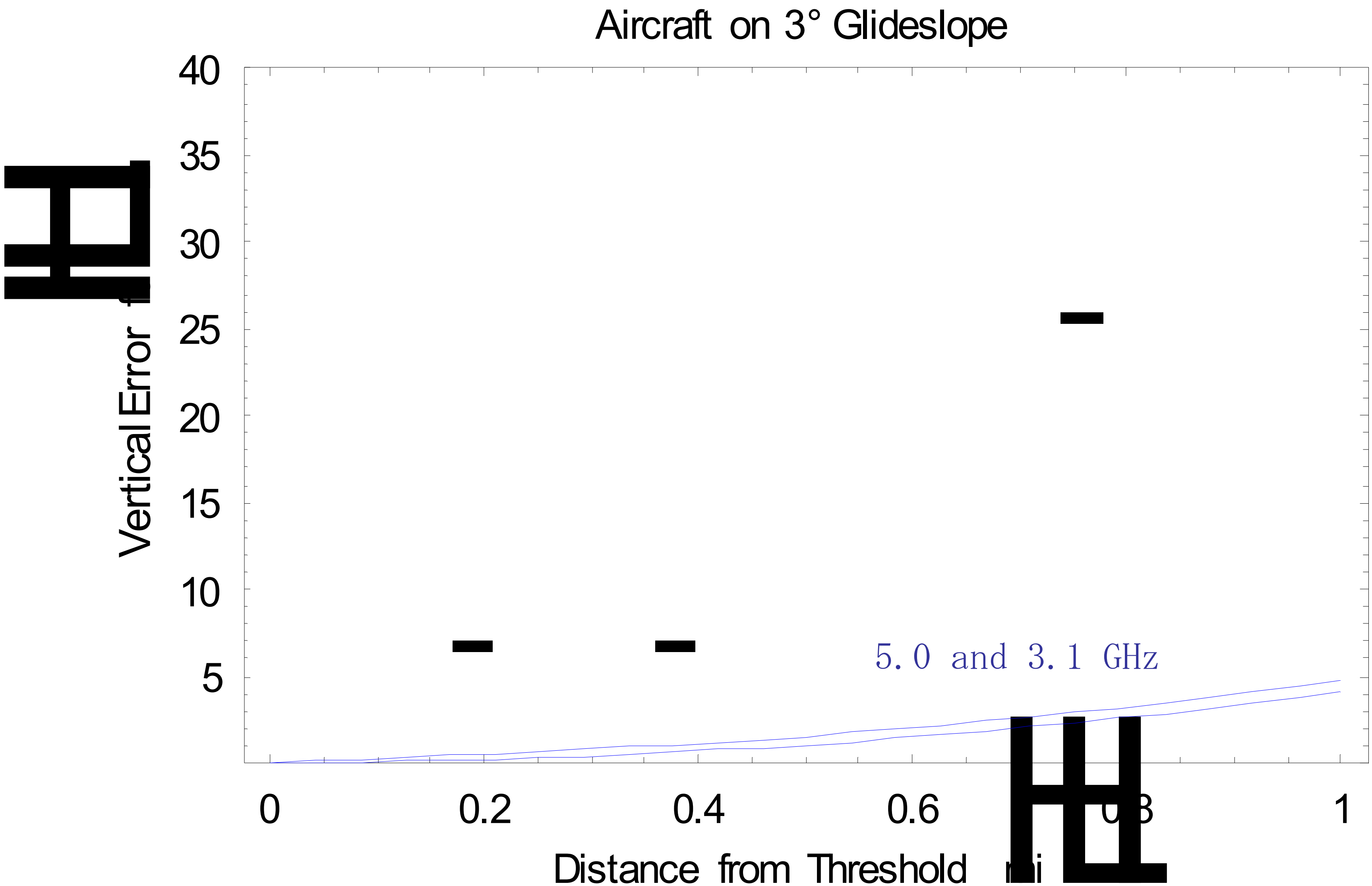
Parameters of Design Example

Interferometer		
Horizontal Baseline	5	ft
Vertical Baseline	1	ft
Frequency	5 or 1	GHz
Waveform and Link		
Transmitter Peak Power	2 (1 mi) or 600 (20 mi)	W
Transmit Gain	-3	dB
Receive Gain	0	dB
Pulse Length	2	ms
PN Code Bandwidth	> 100	kHz
Margin	6	dB
Data Rate	1000 bits	per reply
Evaluation Scenario		
A/C on Glide Slope	3	deg
Range	0-20	mi
Fading (max)	20	dB

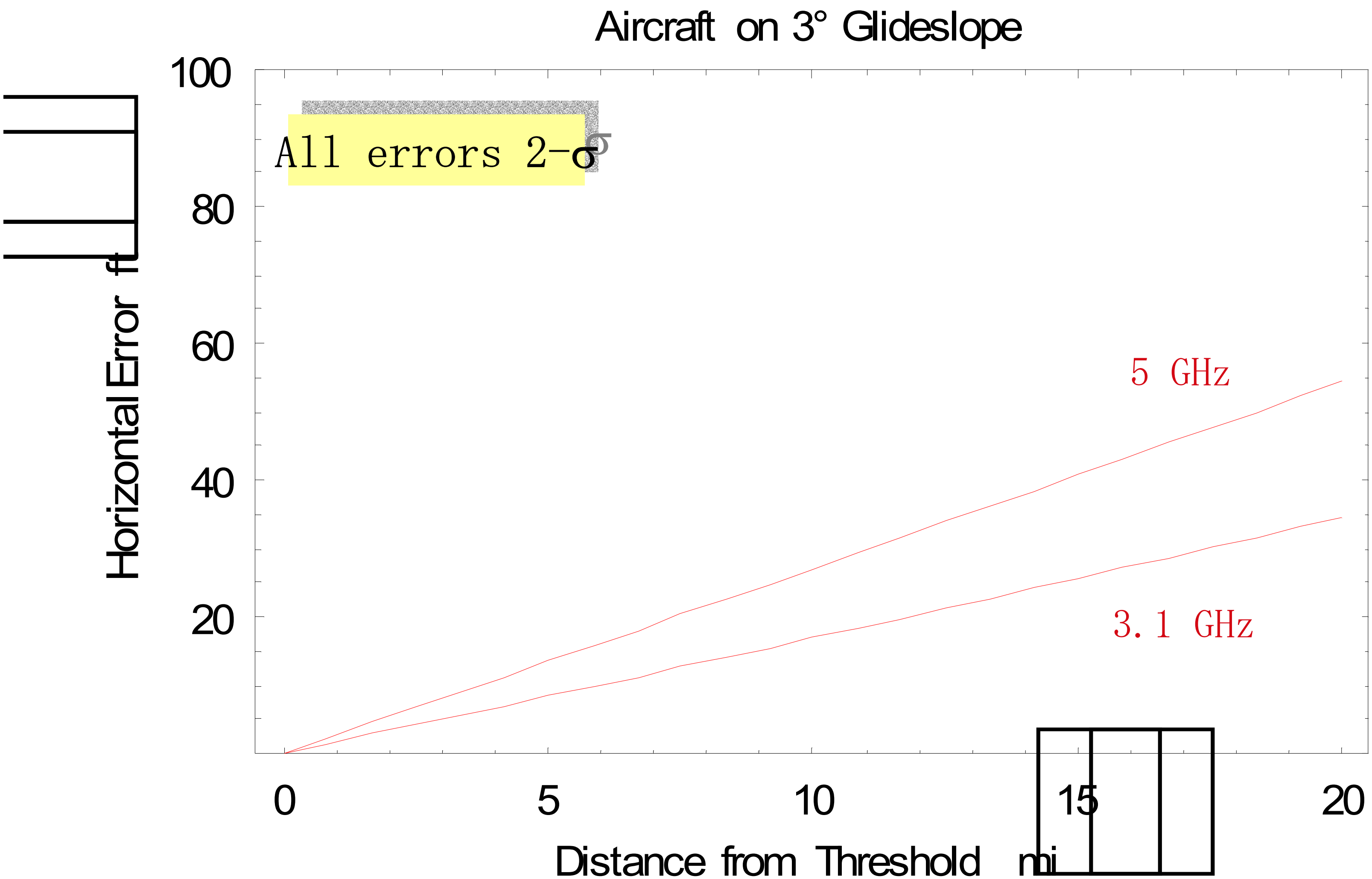
Horizontal Error—C-Band and L-Band



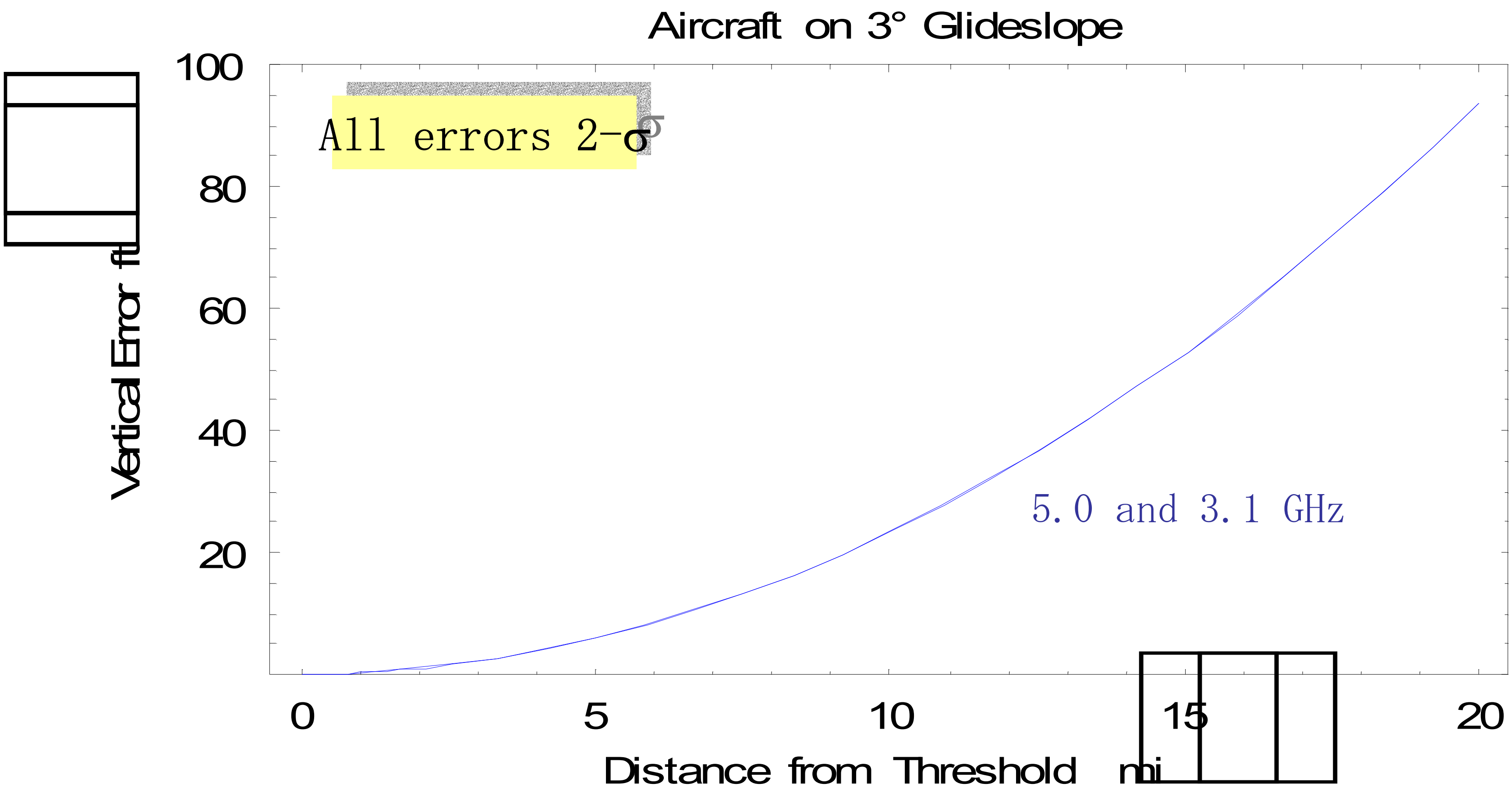
Vertical Error—C-Band and L-Band



Horizontal Error—5.0 and 3.1 GHz



Vertical Error—5.0 and 3.1 GHz



Multipath Errors

- Multipath resulting in flat fading has been shown to have little effect on performance
- Spatially-selective multipath can be a significant error source in interferometry at these low elevation angles and solutions have to be studied.
- Multipath suppression techniques include:
  - Siting
  - Decorrelation via high bandwidth waveform
  - Low elevation antenna pattern roll off
  - Time- and space-domain signal processing
- Appropriate combinations of these techniques can be used to bring multipath under control.

Summary Comments

- **Augmented interferometry can provide a ground-derived approach and landing system having performance comparable to or better than GPS.**

- **Equipment is compact enough for near-runway siting, but may be placed at other locations as well.**

- **Good performance can be obtained at a variety of frequencies.**